Research Summary

Modeling Fluid Transfer from Shale Matrix to Fracture Network

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Problem Statement - A

Suggested Study - A

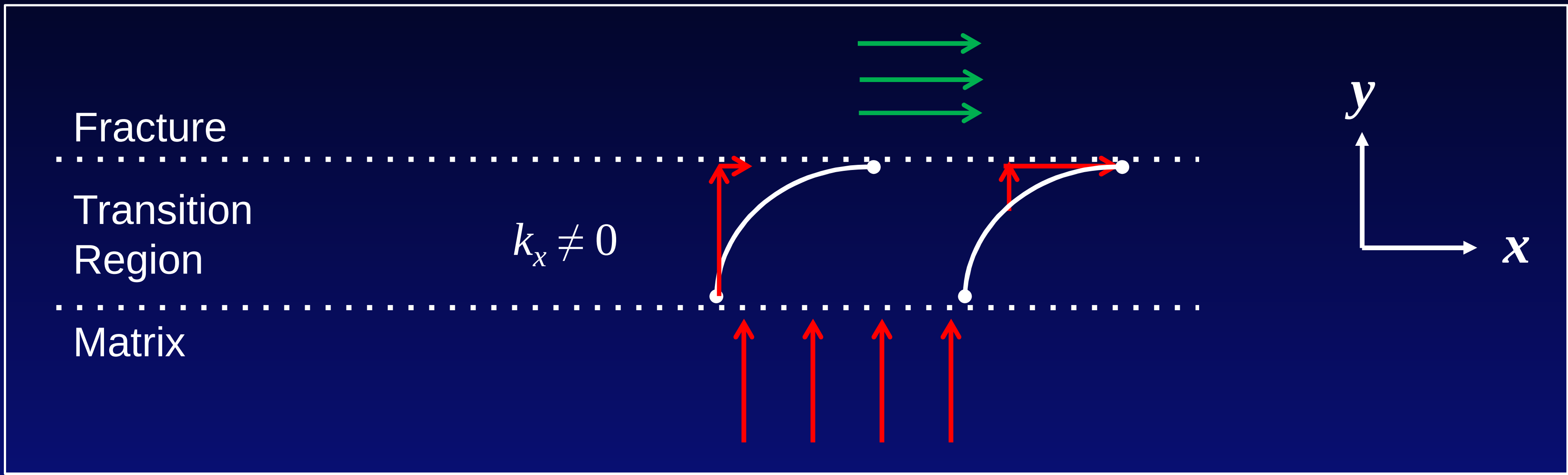


Figure 1: Investigated Behavior for Flow From Matrix to Fracture

- We are interested in investigating the possible contribution of the tangential velocity component (v_x) to the mass flux going into the fracture (drag forces).

Scope of Study - A

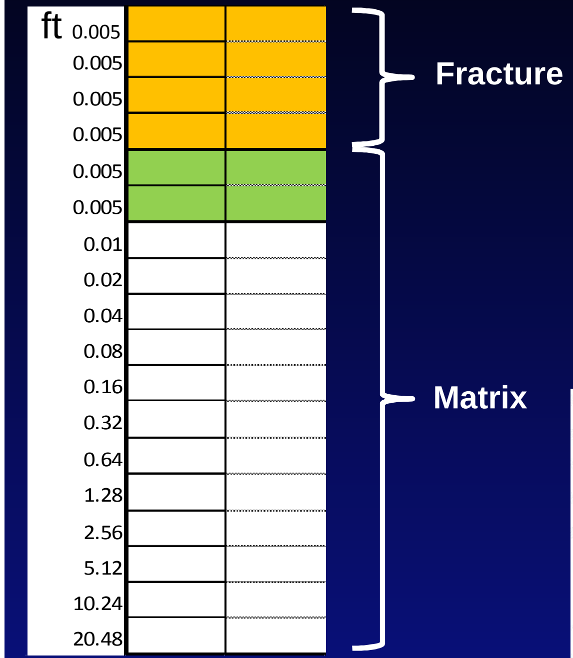


Figure 2: Conventional Modeling

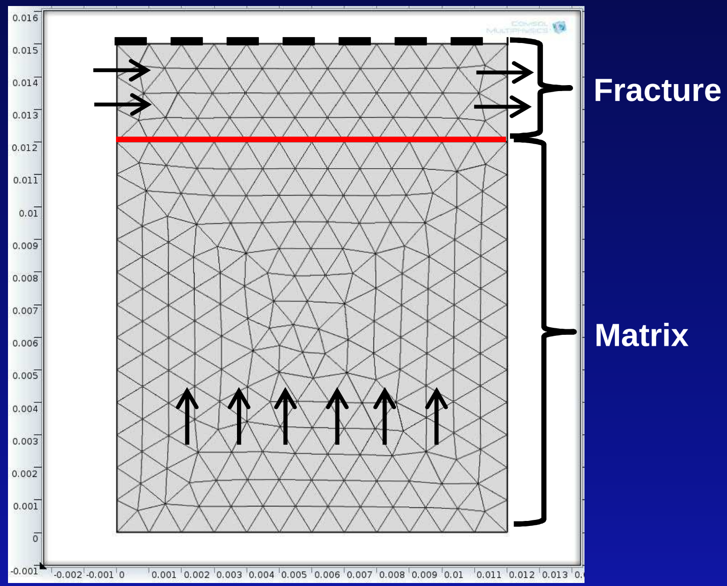


Figure 3: Modeling with COMSOL

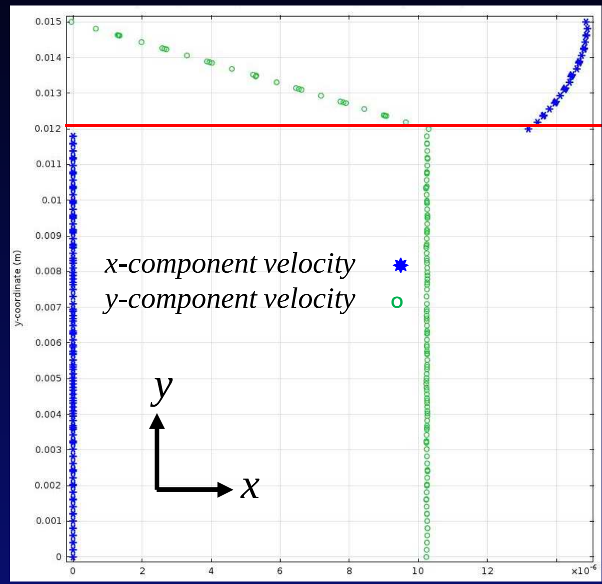


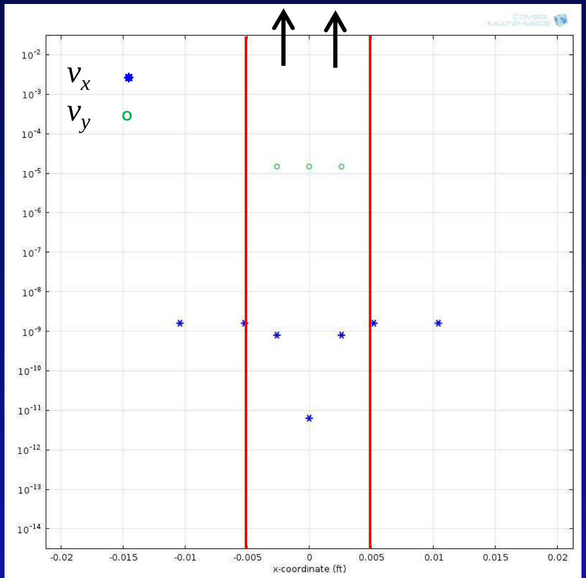
Figure 4: COMSOL Results

Results Review - A

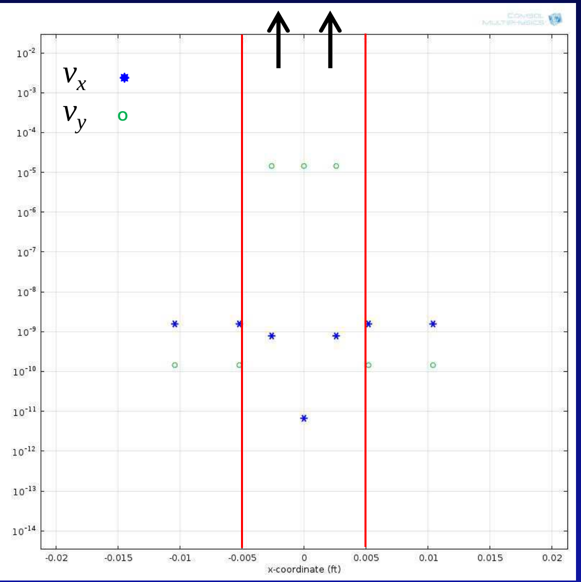
- Results are dependant on (w_f/h_m), (k_f/k_m), x_f and boundary conditions (pressure, slip/no-slip wall).

Table 1: Sample Sensitivity Range

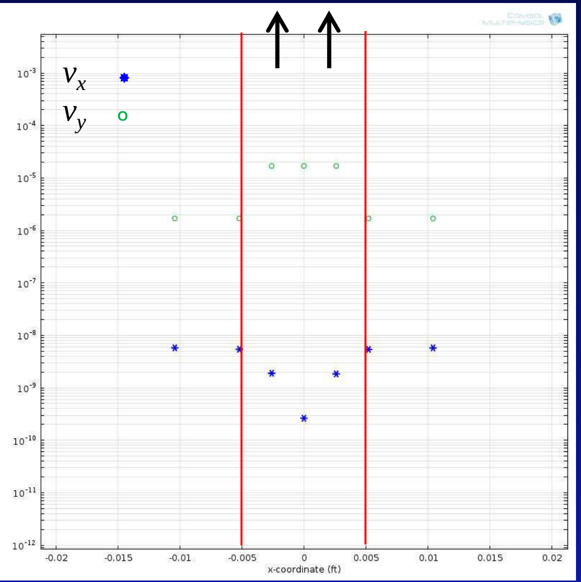
w_f/h_m	k_f/k_m
1:1	10
1:2	100
1:4	1,000
1:10	10,000



a) No Tangential Contribution



b) Suggested Study k_f/k_m = 100



c) Suggested Study k_f/k_m = 10,000

Figure 5: COMSOL Results for k_f/k_m Sensitivity

Results Review - A

- Research is ongoing, we are trying to find a more accurate/detailed methods/equations and better setup of the problem.
- Is it possible to generalize the results in the form of a conventional transfer function?

Problem Statement - B

- Multi-stage hydraulic fracturing (HF) is necessary for unconventional wells to be economical.
- HF can increase the permeability of naturally fractured reservoirs by opening pre-existing closed fractures (shear dilation and fluid leak-off).
- Stimulated Reservoir Volume (SRV) is assumed to have uniform properties (k_{nf} and ρ_f).

Problem Statement - B

- How accurate are the models representing the SRV in terms of average natural-fracture properties (k_{nf} , ρ_f, etc.)?

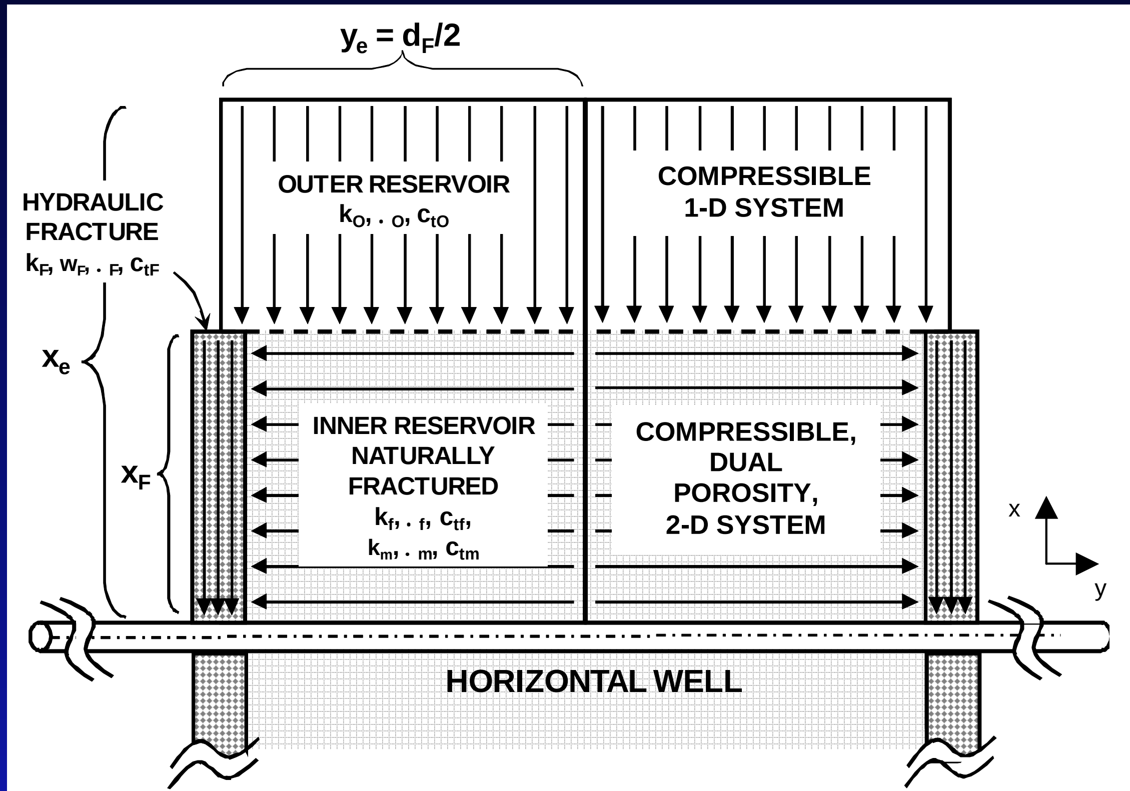


Figure 6: Tri-linear Flow Model (Ozkan et al., 2009)

Problem Statement - B

- Induced stress is maximum near HF → increased microseismic events are observed.

- As we move further from HF k_{nf} and ρ_f will decrease.

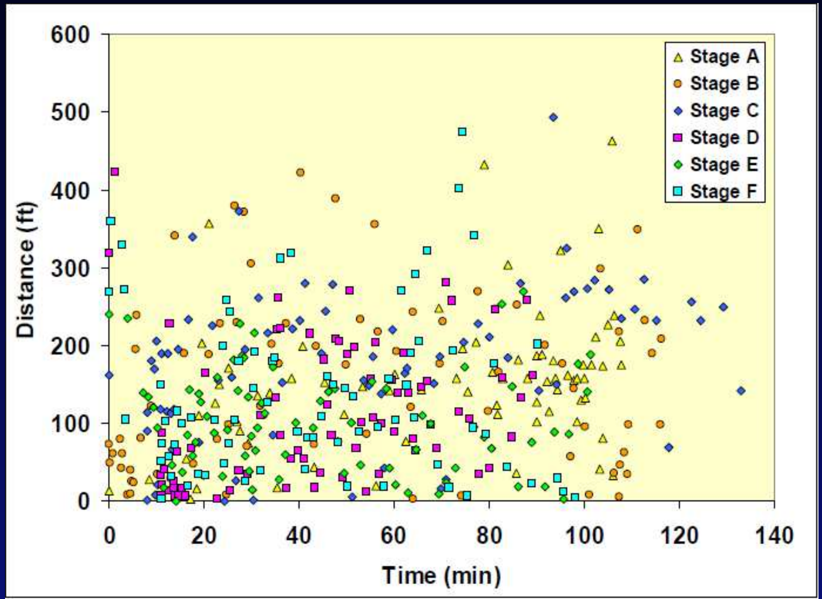


Figure 7: Microseismic Events for Horizontal Well with Multi-stage Hydraulic Fracturing (Warpinski 2009)

Scope of Study - B

- Derive an analytical solution assuming a linear composite SRV between hydraulic fractures.

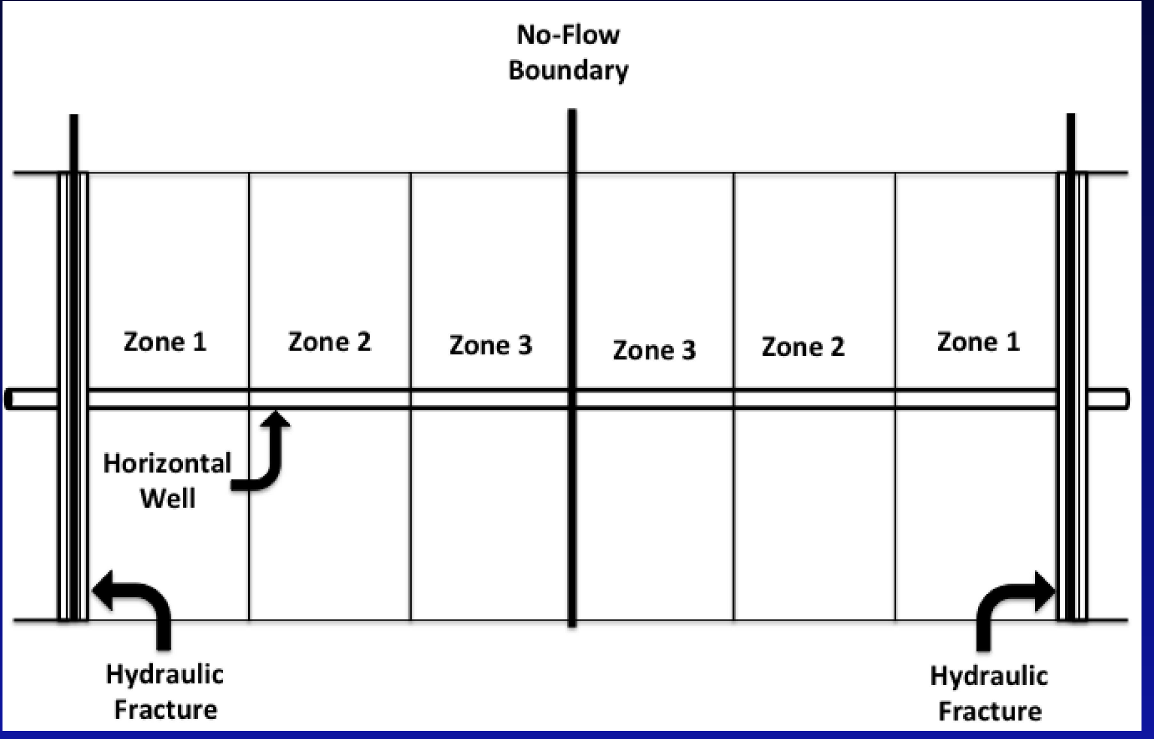


Figure 8: Example of Composite SRV

Scope of Study - B

- Compare the production responses obtained from the linear-composite and "homogenous" SRV models:
  - Is homogenous SRV assumption valid?
  - What are the limitations?
  - Are there any diagnostic features of production data indicating composite SRV?
  - Can the results be generalized for continuously changing natural fracture properties away from the hydraulic fracture?

Analytical Modeling - B

- Identical fractures uniformly distributed along the well.
- Model the region between two hydraulic fractures.
- Tri-zone linear composite SRV between fractures.
- No-flow beyond SRV.

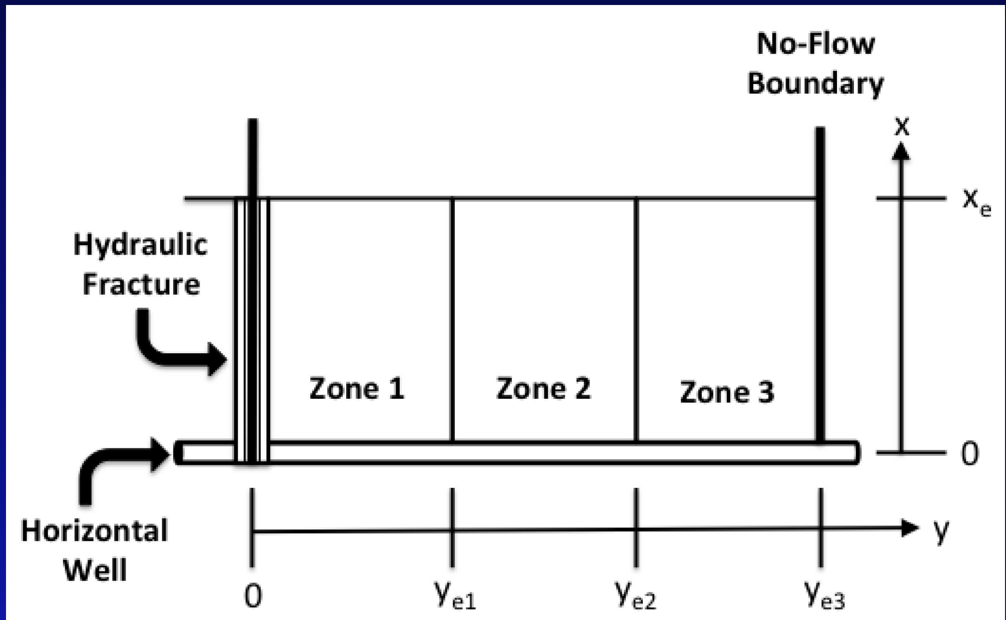


Figure 9: Tri-zone Composite SRV

Analytical Modeling - B

Solution:

$$\bar{p}_{wD} = \frac{\pi}{sC_{FD}\sqrt{\alpha_F}\tanh\left(\sqrt{\alpha_F}\right)}$$

$$\alpha_F = \frac{2\beta_F}{C_{FD}} + \frac{s}{\eta_{FD}}$$

$$C_{FD} = \frac{k_F w_F}{k_r x_F} \qquad \eta_{FD} = \frac{\eta_F}{\eta_r} \qquad \eta = \frac{k}{\phi c_t \mu}$$

Analytical Modeling - B

Solution (Continued):

$$\beta_F = \sqrt{s_1}\frac{\sinh\left[\sqrt{s_1}\left(y_{e1D}-\frac{w_D}{2}\right)\right]}{\cosh\left[\sqrt{s_1}\left(y_{e1D}-\frac{w_D}{2}\right)\right]-\frac{\Omega}{2(1+\Omega)}}$$

$$\Omega = \frac{\sqrt{\eta_1}}{\sqrt{\eta_2}}\left\{\frac{\tanh\left[\sqrt{s_2}\left(y_{e1D}-y_{e2D}\right)\right]}{\exp\left[\sqrt{s_1}\left(y_{e1D}-y_D\right)\right]}\right\}$$

$$\times\left\{1+\left(\frac{k_3\sqrt{\eta_2}}{k_2\sqrt{\eta_3}+k_3\sqrt{\eta_2}}\right)\frac{\exp\left[-\sqrt{s_2}\left(y_{e1D}-y_{e2D}\right)\right]}{\left\{1-\cosh\left[\sqrt{s_2}\left(y_{e1D}-y_{e2D}\right)\right]\right\}}\right\}$$

$$s_i = \frac{s}{\left(\eta_i/\eta_r\right)}$$

Work to be done - B

Solution (Continued):

- Solution defaults back to the "homogeneous" SRV solution for uniform properties (or single zone).
- Computational code is being developed.
- The next step is to derive a general solution for n-zone linear-composite SRV model.

Thank you